

Package for Transferable Discharge Permits Game

TDP Game: Instructor's Guide

This file contains the following information:

1. The guide for the person running the game.
2. Handouts to give to participants
3. References for other TDP games that are available on the internet or economics journals.

Objectives and General Points

The objective of the game is to simulate a trading regime to exchange rights to some currently unpriced (or underpriced) environmental or natural resource, and illustrate how trading may lead to an efficient level of pollution (or whatever the good is). A number of scenarios can be tried to illustrate additional points such as the role of imperfect competition in the form of few traders, what happens when conditions change for a firm, what happens when a new firm enters, and so on. The number of scenarios attempted will depend on the time allotted, group involved, what principles you want to illustrate. In the case below, the rights are to emit a physical quantity of pollution. The game could readily be adapted to trading any other sort of right, such as water rights. No matter what happens in the actual game, the participants should come away with a very practical sense of how these sorts of markets might work (and not work well).

If one is running the game in a course setting, it should be done after the concepts of a tradeable permit have been discussed in theory. If it is an environmental economics game, it is generally done after the students have covered the basic model (equating marginal damages to marginal abatement costs) and are discussing environmental policy options. If the game is being run outside of a classroom setting, some more preparatory work (and/or simplification of the game) is probably a good idea. The players can get too focused on details not relevant to permit trading or not be comfortable enough with the underlying theoretical concepts to trade (or try to make it harder than it is, as was the case in our game). I'll note areas where it can be simplified.

The instructor/regulator will need very few props:

- File cards for the permits and to hand out to firms for changes in scenarios.
- An overhead, whiteboard, to write information about trades on.

How to Proceed

If you want to introduce a non-producing buyer of permits (in our case the NGO played by Jack) who enters in a later scenario, have a non-player (teaching assistant, for example) distribute the WTP survey to fund research for an NGO on GHG and global climate change. Give them a few minutes to fill in their response and collect the forms. Don't tell them what the survey is for. The survey will provide the funds for the NGO to bid for the permits in the later scenario. This wrinkle can be eliminated if you want to have a simpler (and shorter game).

Divide group into 6 firms. Should have no fewer than 2 people per firm. You can modify the game by adding more firms, but then the computation (for you) of the efficient equilibrium becomes more complex. I wouldn't have fewer firms or the market is likely to never be competitive.

Next, hand out the material: (1) general instruction sheet; (2) info sheet for each firm – tell them they should not reveal their info sheet to any other firm (or they may suffer dire consequences); (3) spreadsheet and discussion sheet for each firm. Make sure there are enough copies so they can work on these during the game. In a class setting, you could go over the principles of the game ahead of time, but I wouldn't hand out the information with the equations or some collusion may occur before the game.

The marginal abatement cost functions for the 6 firms are as follows: [note these firms need not be in the same country – can tell them whatever one wants to set the stage.] A key point here is that the MACs differ considerably across and within industries. A permit market requires differences in MACs to operate, but this can also create interesting issues depending on how the permits are allocated. How to allocate the permits (if not an auction initially) is something you can experiment with.

Coal-fired power plants (firms 1 and 4)

$$MAC_1 = 100 - 2Z_1$$

$$MAC_4 = 100 - 4Z_4$$

Petroleum refineries (firms 2 and 5)

$$MAC_2 = 200 - 5Z_2$$

$$MAC_5 = 300 - 20Z_5$$

Cement producers (firms 3 and 6)

$$MAC_3 = 300 - 10Z_3$$

$$MAC_6 = 200 - 10Z_6$$

Playing the Game

First scenario: The regulator announces that there is no GHG policy in place (the status quo) and that each firm should compute its profit-maximizing output levels. [Give them a few minutes to do this. This is where we got off on an awkward start. What I intended is that firms simply set their $MAC = 0$ and that determines the level of pollution and because one unit of pollution yields one unit of output, also determines the level of output. Because the game was set up so that firms had positive profits and MC of production are constant, the actual level of output is determinant. This is not what I intended, but that's where confusion occurred. One simple way to eliminate this problem is to tell everyone what their initial emission level is and that will be where $MAC = 0$ and say they are earning positive profits in the short run due to whatever you want to tell them. A much more complex game would involve giving them MC of production curves and have them solve for profit-maximizing output levels that then determine pollution levels. If you do it this way, this initial stage will take more time. I've changed the directions to the firms to simply tell them their initial pollution level.] If you go the simple route, then just have them fill in their profits and output levels etc on the spread sheet, so they can keep track. An even simpler game wouldn't even have the profits, just the objective function to minimize total abatement costs.

2nd scenario: The regulator then announces that at a meeting of the GHG congress, target reductions have been set for each GHG producer. This is an emission standard that is enforceable by shutting down the plant if there is non-compliance. Announce that each firm must reduce its emissions by 20 tonnes per year. [Note their MACs are for annual emissions.] Ask them to compute the impact on their profits. Give them a few minutes to do so. This is the command and control base case that represents a uniform standard – each firm has to meet the same target level of emissions. Because of their different starting points, some firms will have to cut emissions a lot, others not at all. The players should be computing their total abatement costs at 20 tonnes of GHG emissions. This is the area under their MAC curve from their initial output level to 20 tonnes.

3rd scenario: The GHG congress meets again because it has received complaints from a number of industries that the GHG emission standard is adversely affecting their profits and inhibiting growth, jobs, etc. It has decided to convert the standard into a tradeable permit. Each producer will now receive 20 permits, one for each tonne of allowable emissions per year. So the total allowed level of pollution remains at 120 tonnes per year, the same as the uniform standard. These permits are tradeable and divisible into fractions of tonnes, like $\frac{1}{2}$ tonne as a minimum. The rules are that the firm will be allowed to emit as much pollution as it has permits for. It cannot go out of business, i.e., sell all its permits and shut down, thereby avoiding any abatement costs because it will incur a fixed cost of \$1000 to do so. This penalty should be enough to deter any closures and avoid the discontinuity we had by allowing firms to shut down.

The regulator doesn't want to be involved in any trading of permits that occurs, but will help enforce any contracts made. The firms are free to make any bids/offers they want to

each other. Give them a few minutes to decide what to do, then open up the floor for trading. Tell them they have 15 minutes (estimate) to complete any trades they want to make. Don't make it too long. Trading will be like any market: have one trader from each firm come to the front of the room and call out bids and asking prices. The regulator can help by posting these on the board or overhead. At the end of the trading session, have each firm record what has happened to it (# permits traded, price, and effect on profits on their spreadsheet). The regulator should keep track of what is happening to see if they are approaching the efficient equilibrium (solution shown below).

The solution for the efficient equilibrium with total $Z = 120$ tonnes, the efficient permit price is \$50 per tonne. With an identical initial (free) allocation of 20 tonnes per firm, the following would occur (in an efficient permit market) after the trades. You won't tell them this until after the end of the game.

Firm	Z	Permits bought (B) or sold (S)
1	25	B 5
2	30	B 10
3	25	B 5
4	12.5	S 7.5
5	12.5	S 7.5
6	15	S 5

Regardless of whether they reach the efficient equilibrium, announce that the 'year' is over and they again have 20 new permits for the upcoming year and they can start trading again. You may want to repeat this same scenario in another round or even two, after they have had time to see what happened to their profits. Firms may be reluctant to trade at first, want to see what is happening in the market, etc.

If they are sophisticated traders and reached the efficient equilibrium, or you just want to move on, the next scenario brings in the NGO to whom they made a WTP donation at the beginning of the game.

4th scenario: The Ecolecon director now shows up and starts bidding for permits, the amount bid is dependent upon the total payments pledged to it at the beginning of the session. [The Ecolecon director can be left to his/her own devices in this, or briefed on what to do – e.g., bid high enough to disrupt whatever equilibrium was reached, if indeed they got to the efficient equilibrium.] Make sure everyone records the results. Ecolecon can now stay in the game (if it hasn't spent all its money). This is supposed to create a situation of excess demand for permits, the price should rise. Those firms with excess permits to sell will make higher profits in this round than they did before.

5th scenario: Another new year: regulator now takes away all their permits and gives each firm a card that only it sees; where the permits are distributed unequally, according

to the following: Firms 1 and 2 get 40 permits each. All the rest get 10 permits each. Repeat the trading. This should give rise to the potential for some non-competitive behaviour on the part of the firms with most of the permits. They may try to hold out for higher permit prices as firms who only have 10 face high total abatement costs. Alternatively, they may try to dump some excess permits because they are emitting so much pollution that their TAC are quite low. It is hard to predict what will happen.

Also ask them if they want to change their pledge to Ecolecon for that year. If so, hand in a payment card (give them a file card to fill out). Ecolecon may have to sit out if its pledges drop (as they probably will because firms now know how these pledges are being used).

6th scenario: Another new year: The regulator takes away all permits and announces that it will be auctioning them to the firms. The regulator can post an asking price, do an oral auction, or whatever necessary to get them to start bidding. In principle, if the efficient price was reaching with the 'free' allocation of permits, a competitive auction should also lead to the efficient price. There should be no difference.

7th scenario: The regulator visits some of the firms before the trading begins in a new year and gives them a card that indicates that some condition relevant to them has changed. You can try the following: [we never got this far]

Firm #1: "Good news! Due to a shortage of petroleum, the price of electricity has risen to \$150 per unit." [This of course should not change any trading on the margin because it doesn't affect their MAC, just profits]

Firm 2: "Your MC of production have fallen to \$2 per unit because of a technological change. Your MAC curve does not change." {This again should not affect any permit trading]

Firm #3: No change from last year.

Firm #4: "Bad news." Your power plant has been discovered to be discharging toxic chemicals into a nearby river. You are shut down for one year while you fix the problem. This doesn't affect any of your costs, you are just not going to buy permits this year."

Firm #5: "Your engineers have discovered a cheaper way to abate your GHG emissions. Your MAC curve is now: $\$300 - 50 Z_5$." [This means that their TACs are a lot lower and they will now want fewer permits]

Firm #6: "Your cement plant is old and machinery is wearing out. Your MC of production are now \$15 per unit. Your MAC does not change." [This will make the firm need more permits to not incur a loss. In the old efficient equilibrium it needed 15 permits, in this case it needs at least one more].

This should be more than enough to give them a real taste of a market. Give them time to fill out their discussion sheets; hand in a copy to the moderator, keep a copy for themselves and then go through the questions in a discussion with them. Ask each firm to present their views for each question, then discussion. You may want to modify the discussion sheet. These are just suggestions for how to get them to participate. You might not even need a discussion sheet.

Other things to discuss:

1. Show them the equilibrium price and efficient number of permits for each firm if they don't get to this outcome. You can put up an overhead with the MACs of each firm shown and how at \$50, they reach the target level of emissions of 120 tonnes per year and because each firm is paying the same price for a permit, it is a cost effective equilibrium. [If you are doing this in a course, you might give them all the MAC equations and have them prove that this equilibrium minimizes the sum of the total abatement costs for the emitters, i.e., no other price will yield both the target being met exactly and lower sum of TACs across the firms. Have them compare these TAC to those under the uniform standard.]
2. Which firms bought/sold permits and why?
3. What might happen if the costs of closing down a firm for a year or more were much lower than assumed?
4. Have them try to derive the demand curve for permits.
5. What does the supply curve look like? What if the regulator did not tell the firms the total number of permits for sale each year? Would this change anything?
6. Would this sort of market work for GHGs? For other markets? What are some of the key difficulties a TDP market would likely encounter? [They should have seen a number of these illustrated in their game – e.g., imperfect information, no one knows the other firms' MAC curves, collusion, monopoly/monopsony.]
7. A key issue in any permit market is how to allocate the permits initially. What are some alternatives and the pluses and minuses of each method?
8. Should Ecoecon (the NGO) be allowed to bid for permits?

There is lots more to discuss, which could take another full class in a teaching setting. At any rate, they should have fun and learn a lot about how markets can work.

The hand out sheets for the participants follow (corrected for typos and with some modifications to hopefully make it easier to play).

A Tradeable Emission Permit Game for Global Climate Change

Background

Global climate change will affect all nations. Predictions are that average temperatures will rise and there will be more severe weather events. The variance in temperature and rainfall is expected to rise. If ocean levels rise, coastal areas will be inundated. This will adversely affect people and production. Migration to higher elevations may be necessary and valuable ecosystems may be lost. Greenhouse gases – carbon dioxide, methane, and others are the compounds felt to be responsible for global climate change. Emissions of these gases from human activities have doubled in the past 35 years. Scientists and many policy makers argue that all countries must begin to reduce their emissions of greenhouse gases now to help. The difficulty is that greenhouse gases (GHGs) are released from the combustion of fossil fuels, agriculture, and other manufacturing processes (e.g., cement). Emissions cannot be controlled with pollution abatement equipment. Less combustion of fossil fuels or investment in carbon sinks (e.g., forests) to absorb carbon dioxide are the only practical ways to reduce emissions. Reduction of energy consumption will adversely affect current output. This tradeoff between the environment and economy has hampered significant policy action in many countries.

There are proposals to introduce a tradeable emission permit system to help reach GHG targets set by each country. Thus far, no system has been established. Why not? Can a tradeable emission system work? The following game will help illustrate some of the challenges.

Scenarios:

There are 6 firms that release GHGs as a by-product of their production process. They may be in different industries. Each firm will receive data on its production process and the amount of GHGs produced per unit output. A government regulator will be introducing policies in different scenarios that each firm must respond to. Firms will be monitored to ensure that they comply with the regulations. To help firms determine their best strategy, each will receive a work sheet. Firms are assumed to maximize profits/minimize costs. At the end of the activity, each firm will fill out a summary report. The whole group will then discuss the results.

Firm #1

Instructions and worksheet

You are a coal-fired power plant that produces electricity that can be sold at a constant price of \$100 per unit. Your marginal costs of producing electricity are \$50 per unit. Each unit of electricity you produce also produces one tonne of GHG pollution. Your marginal costs of abating GHGs are given by:

$MAC_1 = 100 - 2Z_1$ where Z_1 is the tonnes of GHGs you release.

Your initial level of emissions is 50 tonnes of GHGs per year.

A government regulator will be announcing various policies to help reduce GHG emissions. Your job is to choose a pollution level (which also then determines your output level) that minimizes your total abatement costs.

If you cease production in any year, you will incur a fixed charge of \$1000 to cover costs of closing your plant and laying off your work force.

To help your calculations, a spreadsheet is attached.

Circumstances may change during this regulatory period. The regulator will inform you of any changes.

Firm #2

Instructions and worksheet

You are a petroleum refinery that sells diesel fuel at a constant price of \$50 per unit. Your marginal costs of producing diesel fuel are \$10 per unit. Each unit of diesel fuel you produce also produces one tonne of GHG pollution. Your marginal costs of abating GHGs are given by:

$MAC_2 = 200 - 5Z_2$ where Z_2 is the tonnes of GHGs you release.

A government regulator will be announcing various policies to help reduce GHG emissions. Your job is to choose a pollution level (which also then determines your output level) that minimizes your total abatement costs.

Your initial level of emissions is 40 tonnes of GHGs per year.

If you cease production in any year, you will incur a fixed charge of \$1000 to cover costs of closing your plant and laying off your work force.

To help your calculations, a spreadsheet is attached.

Circumstances may change during this regulatory period. The regulator will inform you of any changes.

Firm #3

Instructions and worksheet

You are a cement producer who can sell your product at a constant price of \$20 per unit. Your marginal costs of producing cement are \$5 per unit. Each unit of cement you produce also produces one tonne of GHG pollution. Your marginal costs of abating GHGs is given by:

$MAC_3 = 300 - 10Z_3$ where Z_3 is the tonnes of GHGs you release.

A government regulator will be announcing various policies to help reduce GHG emissions. Your job is to choose a pollution level (which also then determines your output level) that minimizes your total abatement costs.

Your initial level of emissions is 30 tonnes of GHGs per year.

If you cease production in any year, you will incur a fixed charge of \$1000 to cover costs of closing your plant and laying off your work force.

To help your calculations, a spreadsheet is attached.

Circumstances may change during this regulatory period. The regulator will inform you of any changes.

Firm #4

Instructions and worksheet

You are a coal-fired power plant that produces electricity that can be sold at a constant price of \$100 per unit. Your marginal costs of producing electricity are \$50 per unit. Each unit of electricity you produce also produces one tonne of GHG pollution. Your marginal costs of abating GHGs is given by:

$MAC_4 = 100 - 4Z_4$ where Z_4 is the tonnes of GHGs you release.

A government regulator will be announcing various policies to help reduce GHG emissions. Your job is to choose a pollution level (which also then determines your output level) that minimizes your total abatement costs.

Your initial level of emissions is 25 tonnes of GHGs per year.

If you cease production in any year, you will incur a fixed charge of \$1000 to cover costs of closing your plant and laying off your work force.

To help your calculations, a spreadsheet is attached.

Circumstances may change during this regulatory period. The regulator will inform you of any changes.

Firm #5

Instructions and worksheet

You are a petroleum refinery that sells diesel fuel at a constant price of \$50 per unit. Your marginal costs of producing diesel fuel are \$10 per unit. Each unit of diesel fuel you produce also produces one tonne of GHG pollution. Your marginal costs of abating GHGs is given by:

$MAC_5 = 300 - 20Z_5$ where Z_5 is the tonnes of GHGs you release.

A government regulator will be announcing various policies to help reduce GHG emissions. Your job is to choose a pollution level (which also then determines your output level) that minimizes your total abatement costs.

Your initial level of emissions is 15 tonnes of GHGs per year.

If you cease production in any year, you will incur a fixed charge of \$1000 to cover costs of closing your plant and laying off your work force.

To help your calculations, a spreadsheet is attached.

Circumstances may change during this regulatory period. The regulator will inform you of any changes.

Firm #6

Instructions and worksheet

You are a cement producer who can sell your product at a constant price of \$20 per unit. Your marginal costs of producing cement are \$5 per unit. Each unit of cement you produce also produces one tonne of GHG pollution. Your marginal costs of abating GHGs is given by:

$MAC_6 = 200 - 10Z_6$ where Z_6 is the tonnes of GHGs you release.

A government regulator will be announcing various policies to help reduce GHG emissions. Your job is to choose a pollution level (which also then determines your output level) that minimizes your total abatement costs.

Your initial level of emissions is 20 tonnes of GHGs per year.

If you cease production in any year, you will incur a fixed charge of \$1000 to cover costs of closing your plant and laying off your work force.

To help your calculations, a spreadsheet is attached.

Circumstances may change during this regulatory period. The regulator will inform you of any changes.

Permit Trading Exercise

Report from Firm # _____

Names of Firm's Directors: _____

Please turn in a copy of your spreadsheet to the regulator

Be prepared to answer the following questions in a group discussion:

1. Which scenario yielded the highest profits to your company? Why?
2. Which scenarios reduced your emissions by the largest amount? Why?
3. Did you encounter any problems in trying to trade permits? If so, what were these and why do you think they occurred?
4. How would your permit trading activities change if your MAC curve fell, i.e., it was cheaper to control emissions?
5. How would your permit trading activities change if the price of your product rose?

6. How would your permit trading change if the regulator reduced the total supply of permits by 25%?
7. From your company's point of view, is permit trading your preferred strategy for reducing GHG emissions compared to a pollution tax or uniform standard? Why or why not?
8. If permits are distributed without charge by the regulator initially, what would you like this to be based on? For example, past emissions, divided evenly among the polluters, other options?

EEPSEA Biennial Meeting
May 2001
SURVEY

Would you be willing to contribute to an environmental research organization, called **ECOLECON**, that studies global climate change? This is a non-profit organization that employs ecologists and economists to do their research and is committed to finding politically feasible and economically efficient policy options to reduce GHG emissions. Ecolecon is internationally renowned for the high calibre of its work. It depends on donations from individuals, companies, and philanthropic organizations to fund its work because it wants to be independent from any government. Your donations are a tax deductible business expense.

Please check the box below that best represents your willingness to support Ecolecon's work. Your pledge will be an annual payment that you can terminate with one year's notice.

I pledge:

- | | |
|-------|-----------------------|
| _____ | zero dollars per year |
| _____ | \$ 5 dollars per year |
| _____ | \$10 dollars per year |
| _____ | \$20 dollars per year |

